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Financial Analysis of Early Stand Treatments in Southwest Oregon

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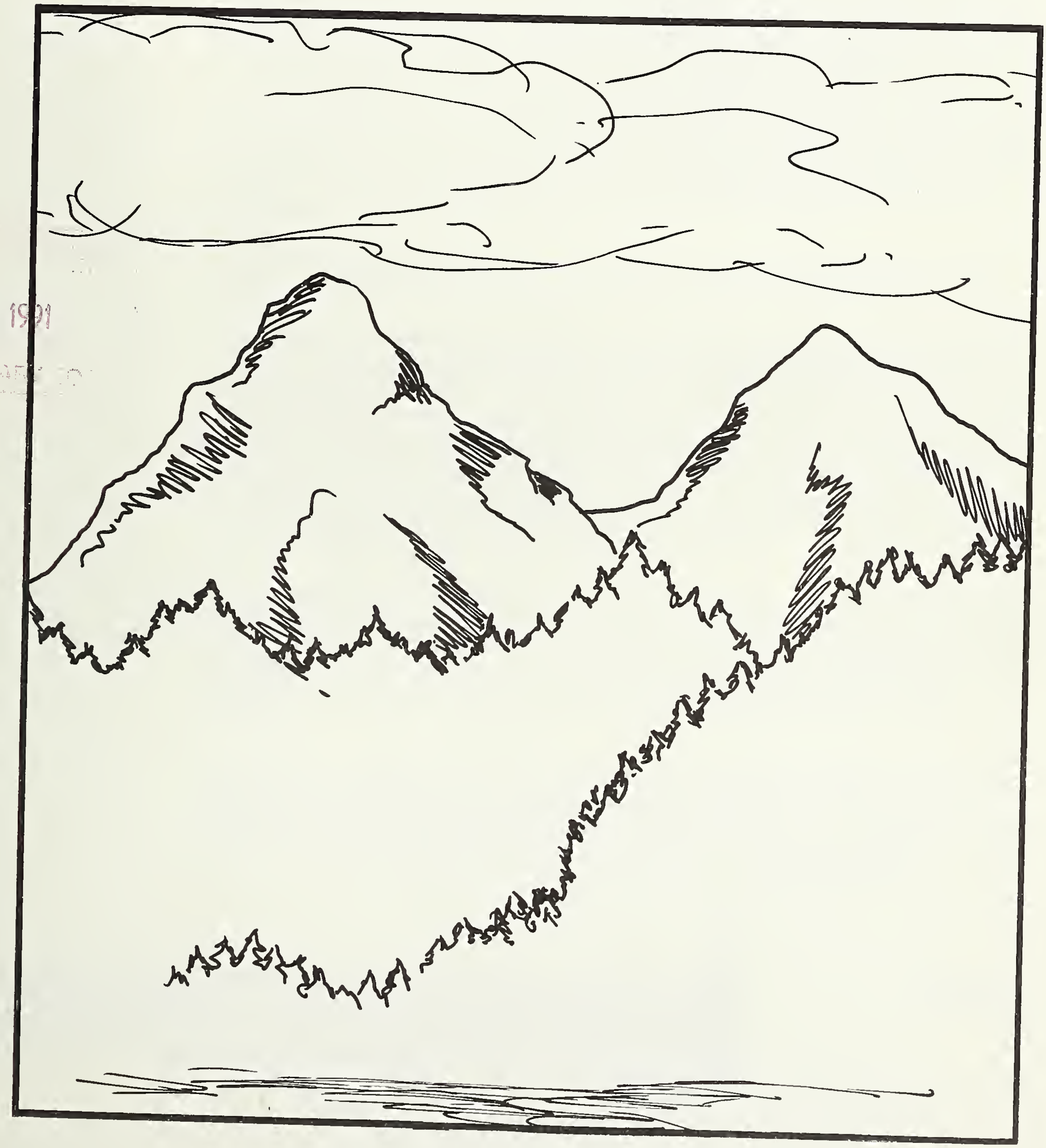

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Abstract

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Management guidelines for economically efficient early stand treatments were developed by identifying treatments that would maximize financial returns over the rotation for coast Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) in southwest Oregon. Short rotations and low stand densities (trees per acre) gave the highest financial returns in all cases. Usually precommercially thinning to a low stand density was more advantageous than planting at low density. Fertilization as soon as possible was always profitable. The financially optimal management regimes for low-cost and high-cost reforestation were identical if the returns justified keeping the site in forest production. Costly treatments were not financially justifiable on low-productivity sites where reforestation is difficult unless investment conditions are favorable.

Keywords: Douglas-fir (coast), financial analysis, stand-level optimization, young-growth management.

Summary

We analyzed how early stand treatments (initial stand density, precommercial thinning, and fertilization) affect the financial returns from management of coast Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) in southwest Oregon. The results showed, for different management situations, how early stand treatments might be varied to obtain the maximum discounted financial return over the rotation. Different management situations were analyzed that represented a cross-section of assumptions about forest management in the area. We analyzed each stand without a reforestation requirement. We discussed the potential effects of minimum reforestation requirements and even-flow constraints.

In the same management situation, a low initial stand density always gave greater financial return than did higher stand densities. In most cases, precommercially thinning to obtain the low stand density was financially worthwhile. Fertilization as soon as possible after the juvenile growth stage always increased the financial return. Costly treatments may not be financially justified under unfavorable investment conditions.

A minimum reforestation requirement may cause the forest manager to harvest fewer stands or plant more trees, or both, but will not alter the financial attractiveness of any discretionary investments. An even-flow constraint can cause an increase in the financial attractiveness of discretionary investments that increase growth.

Contents

Introduction

The costs of reforestation across southwest Oregon can differ greatly because of adverse environmental conditions such as a dry climate and relatively low site classes. The Forestry Intensified Research (FIR) program is a cooperative research effort with a primary objective to develop better methods for achieving acceptable reforestation results in this area. This study extended beyond reforestation and focused on determining which early stand treatments (initial stand density, precommercial thinning, and fertilization) are financially optimal for management situations commonly encountered in southwest Oregon. The term management situation was used to describe the biological and institutional circumstances under which a forest property is managed. The term management regime was used to describe the set of treatments, including early stand treatments, applied to a forest stand through its rotation.

The objective of our study was to evaluate how different early stand treatments affect financially optimal management regimes. The study was a preliminary analysis to determine, for a range of management situations typical of southwest Oregon, how early stand treatments might be varied to obtain the maximum discounted return over a rotation.

Limitations of the Study

This analysis was not intended to be a comprehensive study of the economics of forest management in southwest Oregon, but rather, it was a first attempt at assessing the relative effects of early stand management variables and assumptions on potential financial returns. The methods used will provide procedural guidelines for further economic analyses of early stand treatments in this area.

We did not explicitly analyze the economics of vegetation management for stand establishment (our choice of reforestation assumptions outlined in appendix 1 reflects different vegetation management choices). Although this is a major silvicultural concern in the area, our data were not detailed enough to allow us to evaluate the economics of different methods of controlling vegetation that compete with conifers during the establishment phase.

Our analysis pertained only to timber management costs and revenues and did not consider nontimber aspects (many of which may be subsidized by timber management activities) or indirect effects of timber management on community welfare and stability.

We allowed for mortality losses from animal damage, disease, and fire in a deterministic way only. Foresters often safeguard themselves against such risk factors by carrying a somewhat higher stocking density in young stands.

At high stocking levels, trees have more rings per inch than at lower stocking levels; this characteristic may give the future wood a higher value. We did not consider this element in our analysis. Our price function had a premium for large diameters but no penalty for wide growth rings or a large proportion of juvenile wood.

The allowable-cut base is used to calculate the amount of timber that can be removed from the forest yearly. This base can be expanded by converting unproductive areas into productive stands of commercial tree species. If the forest is managed for even flow and if the original forest has enough harvestable timber, the amount of timber that can be removed annually from the forest can be increased by the amount of the annual growth on the newly productive areas (the allowable-cut effect). We did not consider the allowable-cut effect that would result from converting unproductive forest land in southwest Oregon to productive commercial timberland.

Methods

For each management situation, we identified the regime having the highest soil expectation value (SEV). We used DP/DFSIM (Johnson and Sleavin 1984), a dynamic programming optimization model based on the DFSIM growth and yield simulator (Curtis and others 1981), to develop financially optimal management regimes. The model considers all combinations of levels of the treatments defining a management regime and selects the regime having the highest present net worth (PNW). Present net worth was converted to soil-expectation value (SEV) with the equation:

$$SEV = PNW(1 + i)^r / ((1 + i)^r - 1) ,$$

where

r = the rotation age, and
i = the interest rate.

Although questions have been raised about the applicability of DFSIM in southwest Oregon, during this study, it was the best growth and yield model available.

Management Situations

We defined a management situation by the following variables: ownership category, product prices, interest rate, reforestation difficulty, site productivity, and tax situation.

Ownership Category

We defined two ownership categories for forest land: public and private. Public forest land consisted of land managed by the USDA Forest Service; the U.S. Department of the Interior, Bureau of Land Management (BLM); and the Oregon State Department of Forestry.

Log Prices

The log prices we used were pond values (end-product price minus product manufacturing costs) by diameter class and in dollars per thousand cubic feet. They reflect our assumptions about future log prices in effect when the stands in this analysis will be commercially thinned or harvested. Briggs (1980) developed a method for determining the optimal bucking and allocation of logs to end products and the resulting product value. By using a modification of his procedure, we could start with end-product prices and work backward through the processing procedure to arrive at pond values by diameter class.

We analyzed two price assumptions, designated "low price" and "high price." They were intended to span a range of future price scenarios reasonably likely to occur. The low price was based on 1983 product prices in 1984 dollars and is given by the following equation:

$$\text{price per thousand cubic feet} = 185 + 80.8\,(DBH) - 1.8\,(DBH^2) ,$$

where DBH = diameter in inches at breast height.

The following tabulation shows the low price by diameter class:

Diameter at breast height	Low price	Board feet per cubic foot	Low price
Inches	*Dollars per thousand cubic feet*		*Dollars per thousand board feet*
7	678	1.235	549
8	733	1.674	438
9	785	2.113	372
10	832	2.717	306
11	876	2.987	293
12	917	3.561	258
13	953	3.937	242
14	986	4.142	238
15	1016	4.397	231
16	1041	4.530	230
17	1063	4.880	218
18	1081	5.105	212
19	1096	5.229	210
20	1107	5.348	207
21	1114	5.445	205
22	1117	5.528	202

The high price assumption was based on projected prices for 2030 by the timber assessment market model (Haynes 1987). This price was twice the low price. We converted all prices and costs to 1984 dollars by using the producer price index (Ulrich 1985).

Interest Rate

We used a real rate of return of 4 percent on public lands and real rates of 4 and 6 percent before taxes on private lands. This reflects our expected range of discount rates as used in the forest industry.

Reforestation Difficulty

We used two levels of reforestation difficulty, low cost and high cost, in our analysis. The details of the reforestation assumptions and costs for each are outlined in appendix 1 for all site class and land ownership categories. These two levels of reforestation difficulty are not intended to be all-inclusive of the range of reforestation conditions occurring in southwest Oregon but rather conditions commonly occurring in the area.

Low-cost and high-cost reforestation represent sites within each site class that are considered easy and difficult, respectively, to regenerate. High-cost reforestation generally requires special measures to control vegetative competition, environmental extremes, or animal damage. We assumed that the probability of successful reforestation and the outcome in initial stocking and growth were the same for both low-cost and high-cost reforestation.

Site Productivity

Our choice of site classes was intended to represent a cross-section of timberland productivity in southwest Oregon, where timberland is mostly in site class 3 with some in site classes 2 and 4.

We considered the following site classes:

2 (site index age 50 = 135),
3 (site index age 50 = 113), and
4 (site index age 50 = 92).

These site classes were based on King's (1966) site index tables. Each site class was represented in DFSIM by the site indexes in parentheses above. These are roughly the midpoints of King's site classes.

Tax Situation

Public agencies were not subject to taxes in our study, and we did not consider in lieu payments to counties by Federal land agencies in the analysis. We analyzed private land ownerships both with and without taxes. Taxes are very specific to the circumstances of each private owner. In this study, we tried to generally understand whether imposing a tax changes the financially optimal management regime.

Taxable income was calculated as net revenue: total revenue minus all stand treatment costs. Investment costs were handled as follows: Precommercial thinning was expensed against current ordinary income. Fertilization was capitalized over a period of 5 years. We did not reduce net revenue by reforestation cost for tax purposes. We assumed a 35-percent tax on private landowners. The 35-percent figure is an overall estimate of Federal, State, and severance taxes.

Early Stand Treatments

We defined three early stand treatments: initial stand density, precommercial thinning, and fertilization.

Initial Stand Density and Precommercial Thinning

We analyzed the following initial stand density and precommercial thinning (PCT) combinations:

(1) 430 trees per acre, no PCT;
(2) 300 trees per acre, no PCT; and
(3) 300 trees per acre after PCT.

These stocking levels are the result of planting densities of 540 trees per acre and 375 trees per acre, respectively, with an assumed 80-percent survival rate after planting.

Table 1—Reforestation cost per acre

Site class[b]	Initial stand density	Reforestation cost[a], public land		Reforestation cost, private land	
		Low	High	Low	High
	tpa[c]	*Dollars*			
2	430			258	467
2	300			212	395
3	430	425	675	258	372
3	300	362	565	212	329
4	430	425	645		
4	300	362	545		

[a] Based on average cost figures for easy and difficult reforestation conditions for public and private agencies.
[b] Site class based on King's (1966) site index tables.
[c] Trees per acre.

We obtained estimates of reforestation cost and precommercial thinning costs from interviews with experienced silviculturists in southwest Oregon. We broke down reforestation costs by site class, initial stand density, ownership class, and reforestation difficulty. These cost assumptions are summarized in table 1. A detailed breakdown of each cost figure is provided in tables 4 and 5 in appendix 1..

We precommercially thinned at age 12 on site classes 2 and 3 and at age 15 on site class 4. Precommercial thinning costs were average costs incurred by public and private land management agencies in southwest Oregon:

Site class	Stand age	Public ownership	Private ownership
	Years	*Dollars per acre*	
2	12		69
3	12	111	69
4	15	99	

Fertilization

Analysis showed fertilization as soon as possible gave the highest financial returns. This result is verified by Johnson and Sleavin (1986). The DFSIM program, however, does not reliably predict growth responses to fertilization in the juvenile growth stage. We investigated two options: no fertilization and fertilization immediately after the stand emerges from the juvenile growth stage (age 40 for site class 4 and age 30 for all other site classes). One standard fertilization level was used: 200 pounds of active nitrogen per acre. This is a common level for one application. We used a cost of $52 per acre for private lands (Chappelle 1986) and $88 per acre for public lands (Owen 1984). These are overall fertilization costs including planning, purchasing, and application.

Summary of Management Situations and Early Stand Treatments

Tables 2 and 3 summarize the management situations and early stand treatments that we analyzed for private and public lands, respectively. There were two ownership classes, two price assumptions, two interest rates, three site classes, and two levels of reforestation difficulty. For each management situation, there were three initial stand density and precommercial thinning combinations. There were two fertilization options: no fertilizer and 200 pounds of elemental nitrogen per acre applied as soon as stands were beyond the juvenile growth stage as defined in the DFSIM model. Site classes 2 and 3 were used for private land and site classes 3 and 4 for public land. This reflects the pattern of land ownership among public and private agencies in southwest Oregon.

Table 2—Management situations analyzed for public land in southwest Oregon

		Site class[a] 3		Site class 4	
Reforestation cost[b]	Precommercial thinning	Low price[c]	High price	Low price	High price
		Trees per acre			
Low	No	430	430	430	430
	No	300	300	300	300
	Yes	300	300	300	300
High	No	430	430	430	430
	No	300	300	300	300
	Yes	300	300	300	300

[a] Site class based on King's (1966) site index tables.
[b] Based on average cost figures for easy and difficult reforestation in southwest Oregon.
[c] Log prices. Low prices are based on 1983 product prices; high prices are based on projected prices for the year 2030 (Haynes 1987).

Table 3—Management situations analyzed for private land in southwest Oregon

		Site class[a] 2				Site class 3			
		Low price[b]		High price		Low price		High price	
Reforestation cost[c]	Precommercial thinning	r[d]=4	r=6	r=4	r=6	r=4	r=6	r=4	r=6
		Trees per acre							
Low	No	430	430	430	430	430	430	430	430
	No	300	300	300	300	300	300	300	300
	Yes	300	300	300	300	300	300	300	300
High	No	430	430	430	430	430	430	430	430
	No	300	300	300	300	300	300	300	300
	Yes	300	300	300	300	300	300	300	300

[a] Site class based on King's (1966) site index tables.
[b] Log prices. Low prices are based on 1983 product prices; high prices are based on projected prices for the year 2030 (Haynes 1987).
[c] Based on average cost figures for easy and difficult reforestation in southwest Oregon.
[d] r = interest rate in percent.

Other Stand Treatments

Harvest

Final harvest was allowed every decade from the end of the juvenile growth stage (30 years on site classes 2 and 3 and 40 years on site class 4). We allowed commercial thinnings to take place every decade from the end of the juvenile growth stage to the decade before final harvest.

Logging costs were based on Fight and others (1984). We distinguished between two types of costs in association with harvest: per-unit-volume logging cost and per-entry logging cost.

Per-unit-volume logging cost is a cost per thousand cubic feet of timber harvested. This cost depends on the size (average diameter) and the volume of timber harvested. Tables 6 and 7 in appendix 2 show per-unit-volume logging costs for commercial thinning and final harvest, respectively.

Per-entry logging cost represents the fixed costs associated with each stand entry (equipment setup costs and road changing costs). We assumed a per-entry cost of $60 per acre per entry for both public and private lands.

Timber Sale Preparation and Timber Harvest Administration

We found the cost of both timber sale preparation and timber harvest administration to be significantly lower on private lands than on public lands (Owen 1984, Southern Oregon Timber Industries Association 1985). We treated these costs as a per-acre cost for each entry, based on the assumption that 8,000 board feet of timber per acre is removed in commercial thinning and 30,000 board feet in final harvest. The following tabulation shows the timber sale preparation and timber harvest administration costs:

Ownership	Harvest type	Timber sale preparation	Timber harvest administration
		Dollars per acre	
Public	Thinning	154.00	67.00
	Final harvest	289.00	125.00
Private	Thinning	1.99	2.65
	Final harvest	3.73	4.98

Road Reconstruction

We assumed that a main road network existed from the previous stand entry and that, therefore, road reconstruction costs would be for rehabilitating these main roads for the next stand entry and for constructing spur roads into the stands being thinned or harvested. An average road reconstruction cost of $50 per acre per entry was used for private lands (assuming 5 miles of road per section). A cost of $150 per acre per entry was used for public lands (Craig 1986).

Hauling

Hauling cost was assumed to vary only with the volume harvested (hauling distance was assumed constant). We used a cost of $140 per thousand cubic feet (Owens 1984).

Results

Each of figures 1-12 summarizes one low-cost reforestation management situation. High-cost reforestation did not alter the optimal management regimes except to lower the SEV. Each graph shows the SEV of the optimal management regime for each decadal rotation age from 40 to 100 years, for a given combination of early stand treatments.

The optimal regimes for each management situation were very stable. In most management situations, we found the same stocking level, the same fertilization level, and the same level of precommercial thinning. Optimal management regimes typically had one to two commercial thinnings and a rotation age of 40 to 50 years on private land ownerships and 50 to 70 years on public land ownerships.

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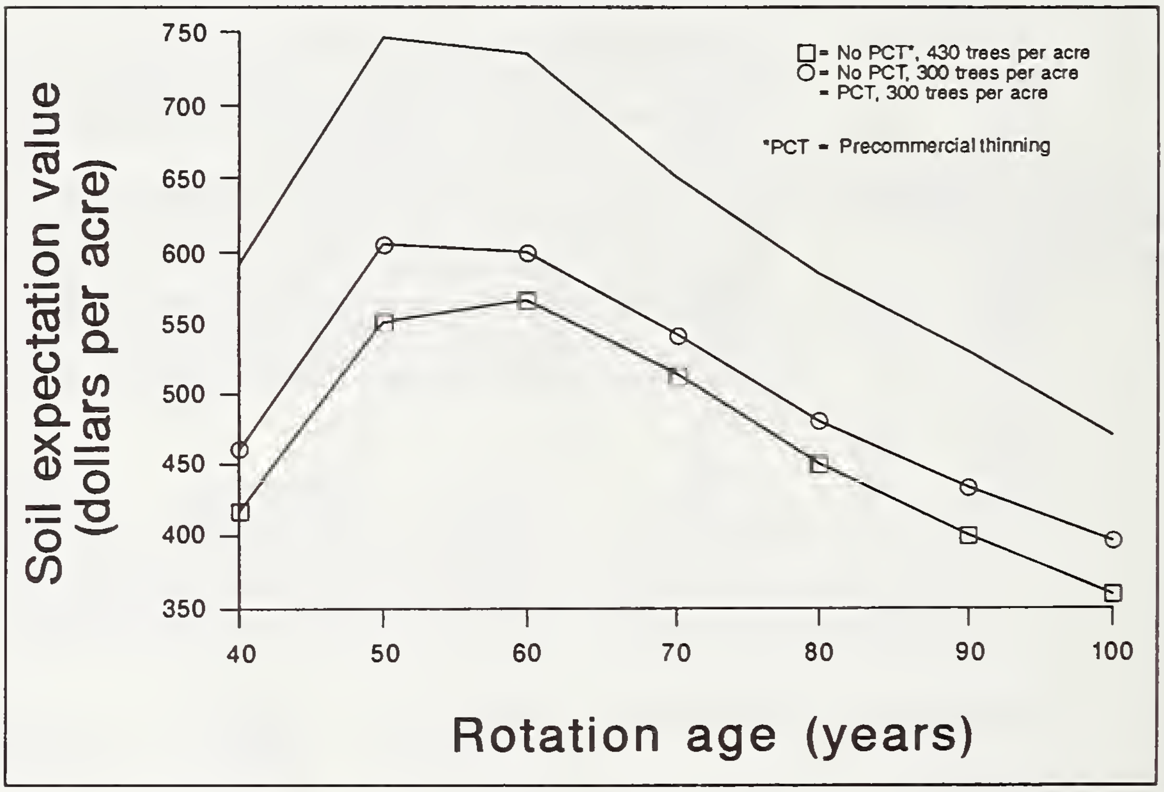

Figure 1—Soil expectation value before taxes on private ownership, site class 2, low price assumption, and 4-percent interest.

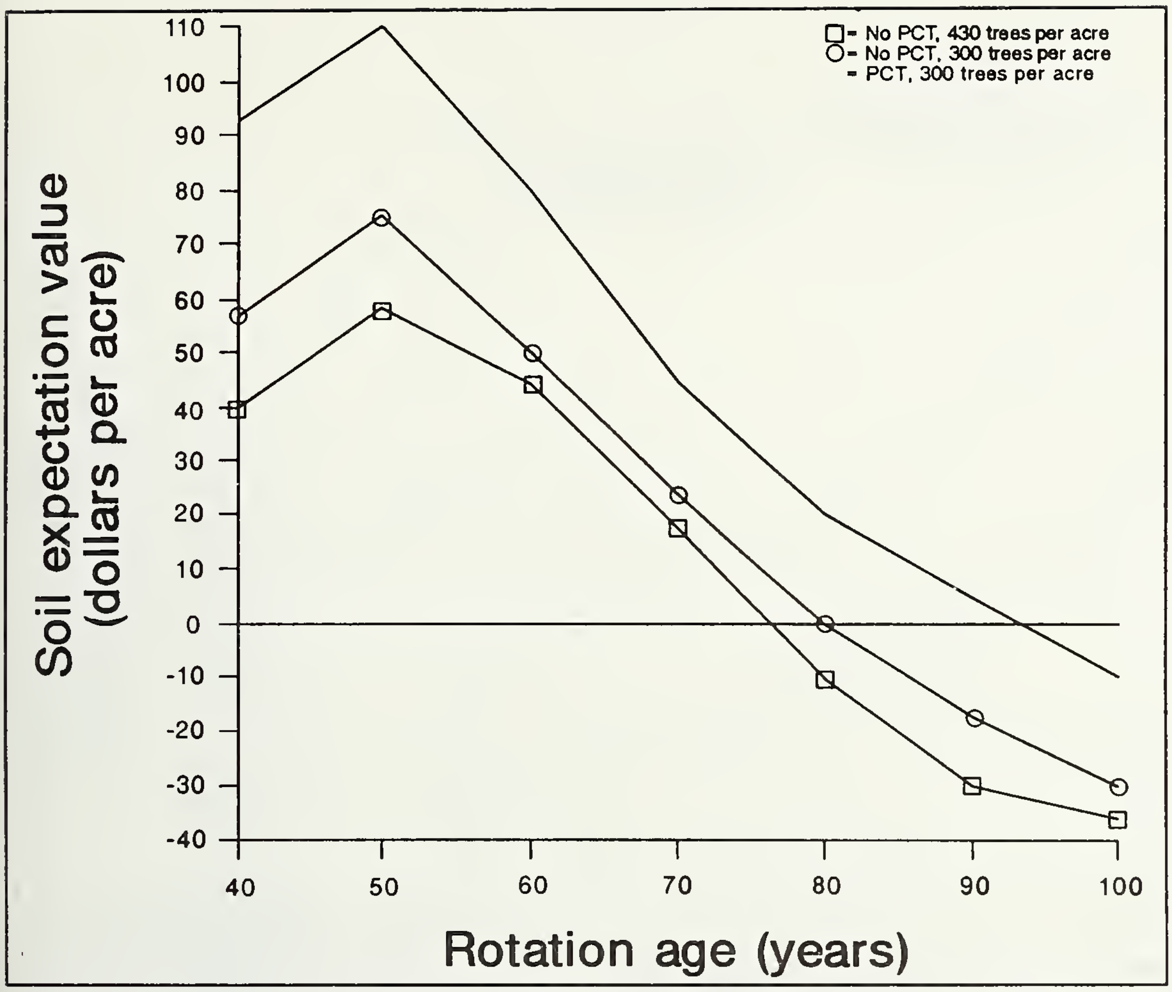

Figure 2—Soil expectation value before taxes on private ownership, site class 2, low price assumption, and 6-percent interest.

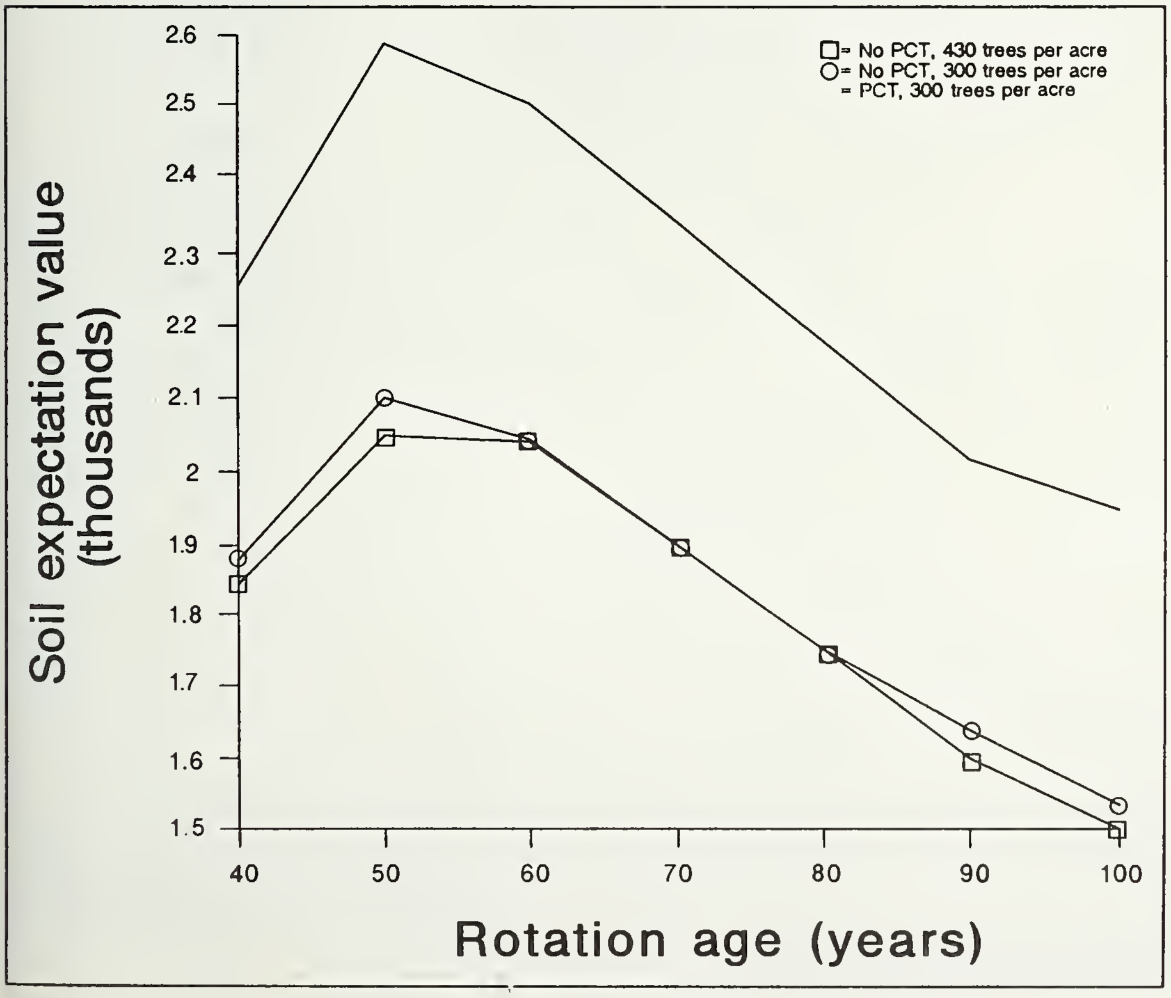

Figure 3—Soil expectation value before taxes on private ownership, site class 2, high price assumption, and 4-percent interest.

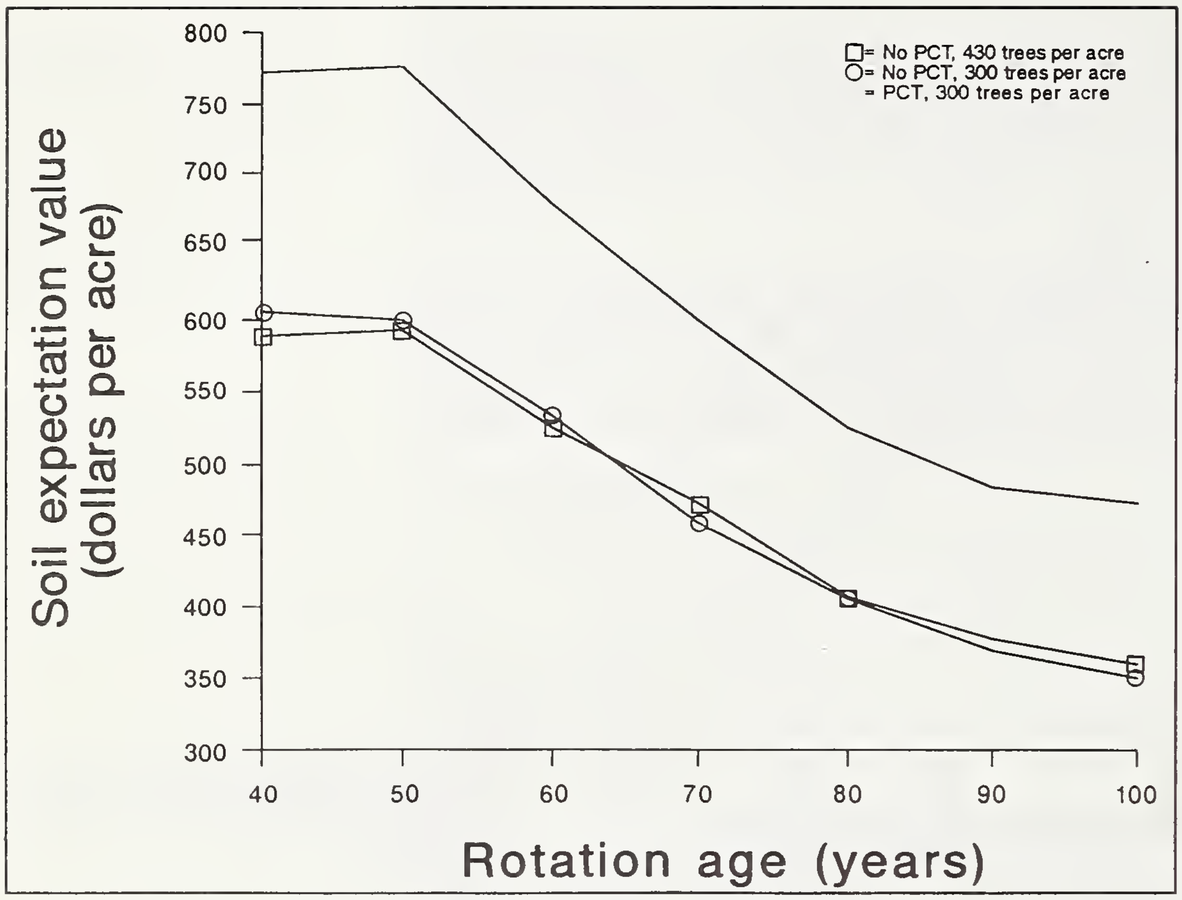

Figure 4—Soil expectation value before taxes on private ownership, site class 2, high price assumption, and 6-percent interest.

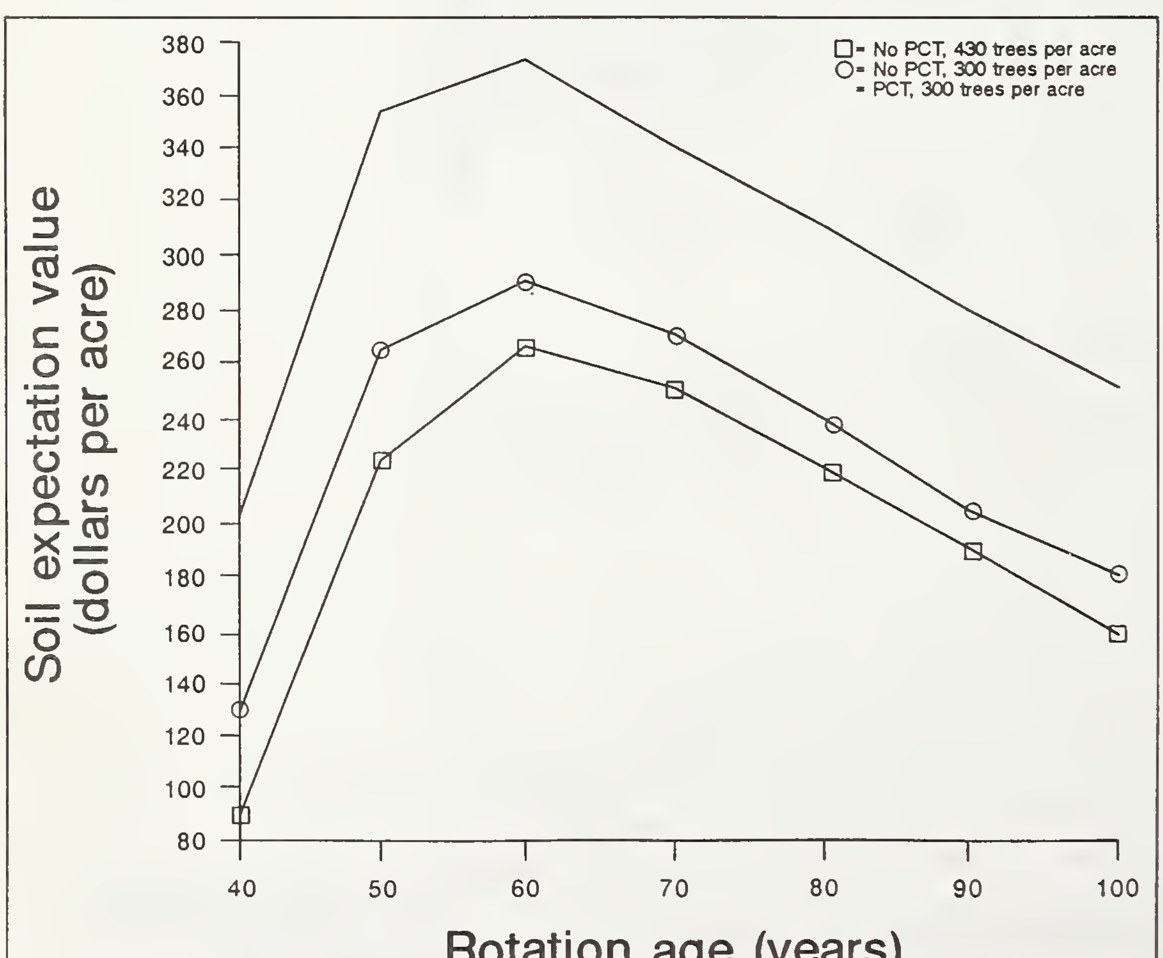

Figure 5—Soil expectation value before taxes on private ownership, site class 3, low price assumption, and 4-percent interest.

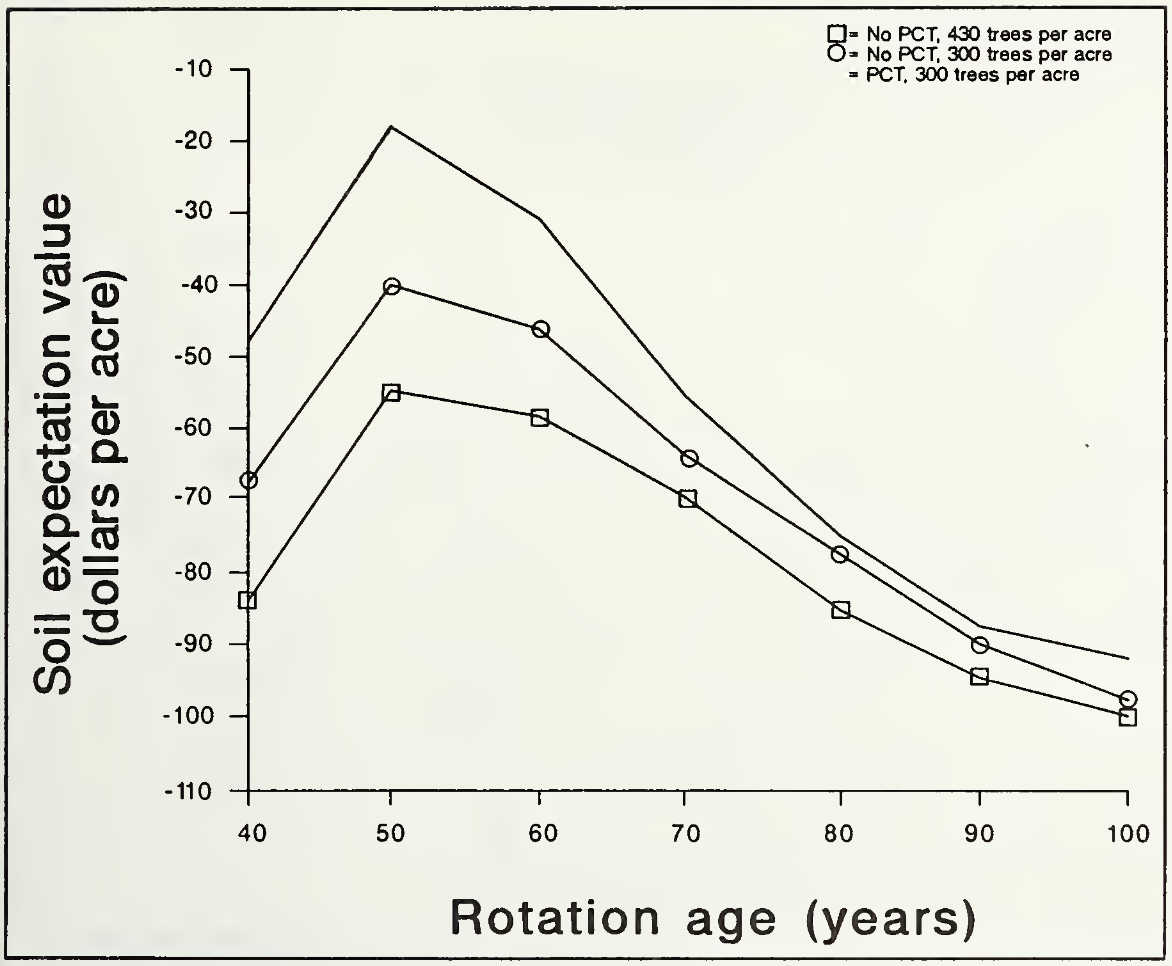

Figure 6—Soil expectation value before taxes on private ownership, site class 3, low price assumption, and 6-percent interest.

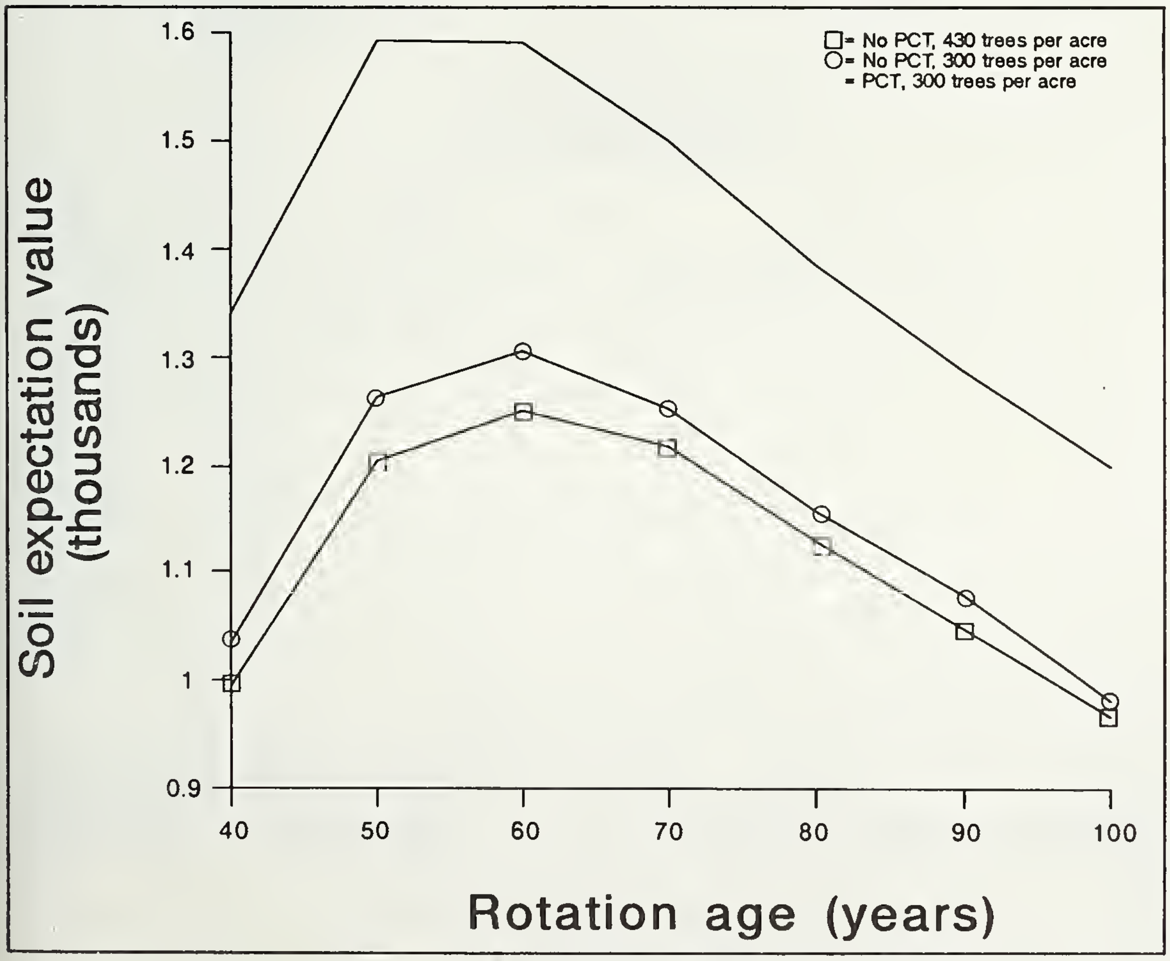

Figure 7—Soil expectation value before taxes on private ownership, site class 3, high price assumption, and 4-percent interest.

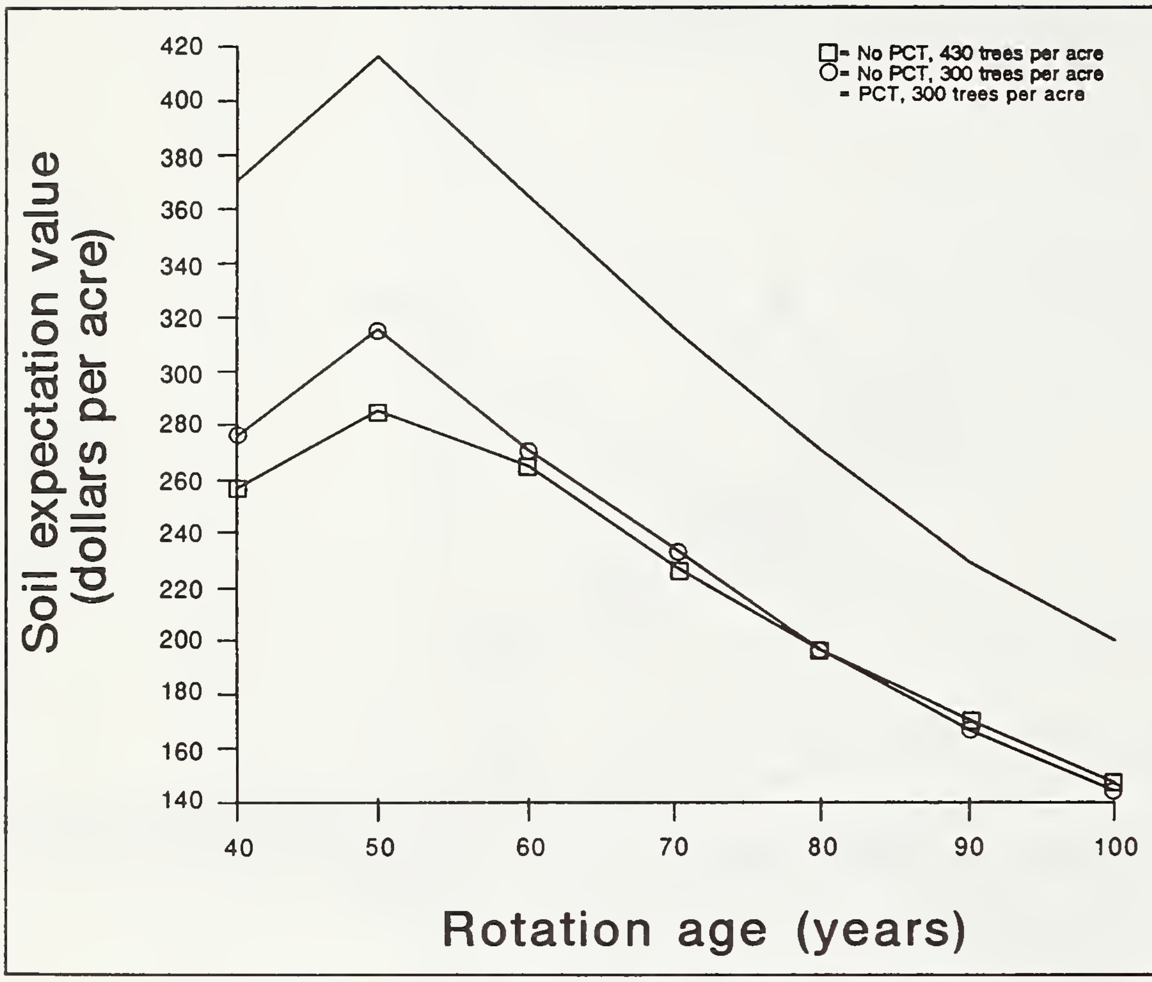

Figure 8—Soil expectation value before taxes on private ownership, site class 3, high price assumption, and 6-percent interest.

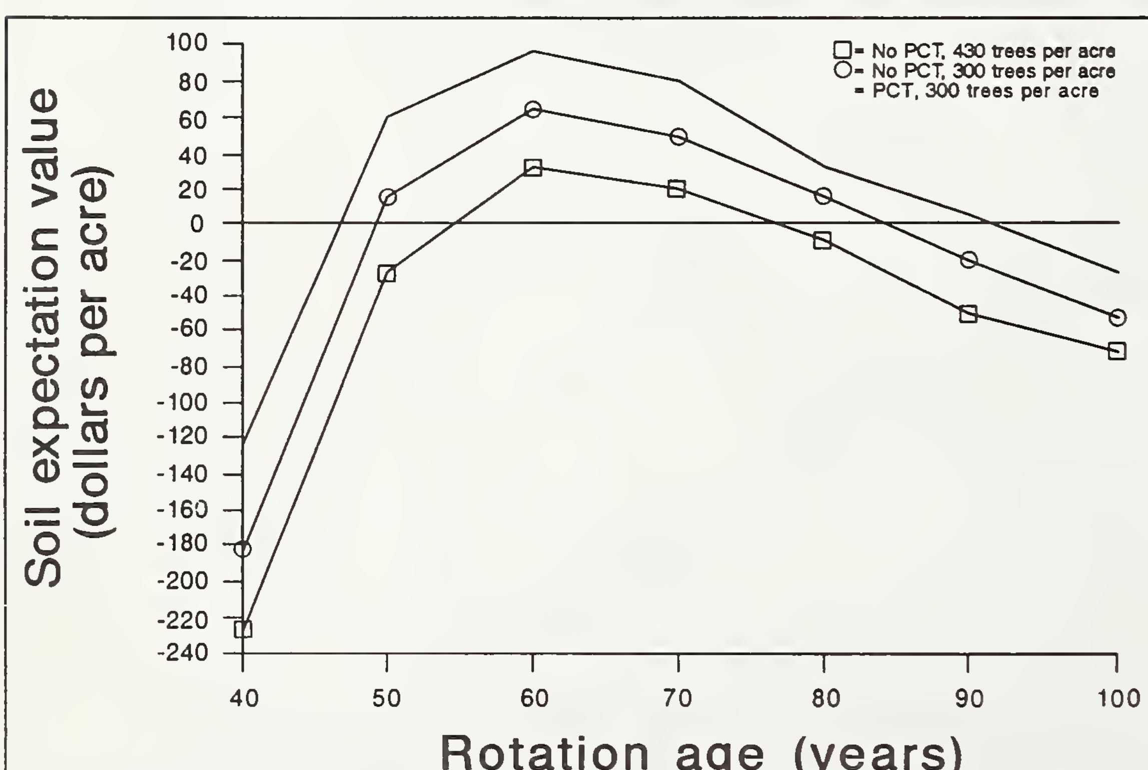

Figure 9—Soil expectation value on public ownership, site class 3, low price assumption, and 4-percent interest.

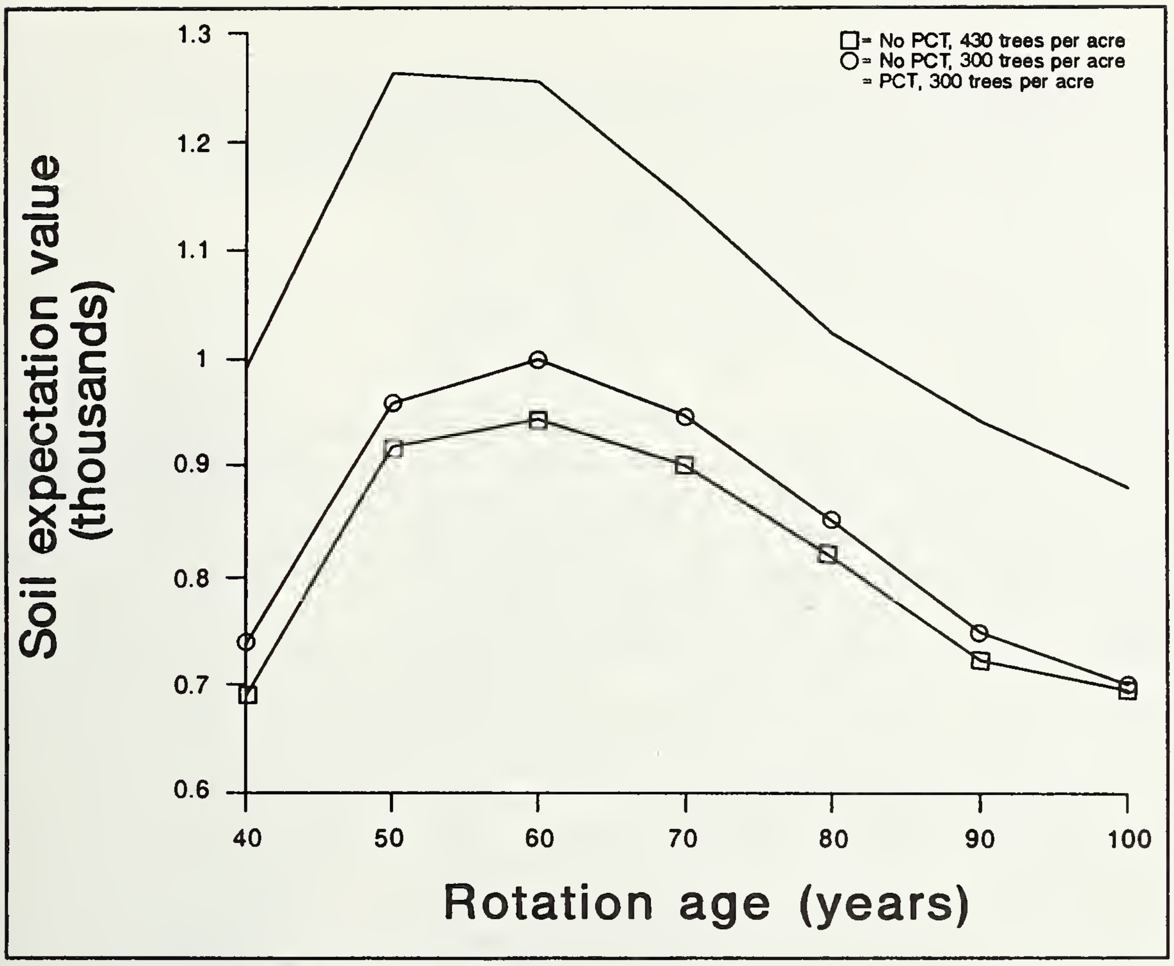

Figure 10—Soil expectation value on public ownership, site class 3, high price assumption, and 4-percent interest.

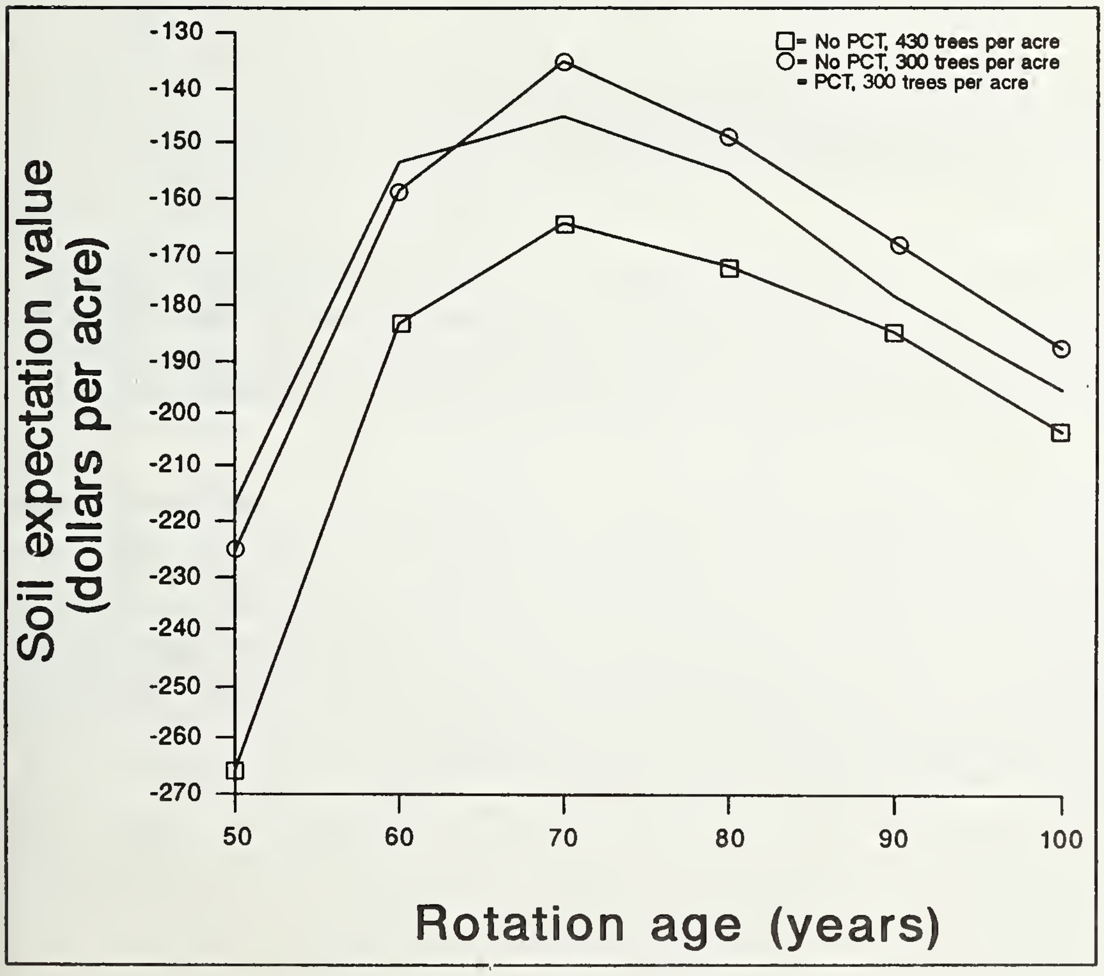

Figure 11—Soil expectation value on public ownership, site class 4, low price assumption, and 4-percent interest.

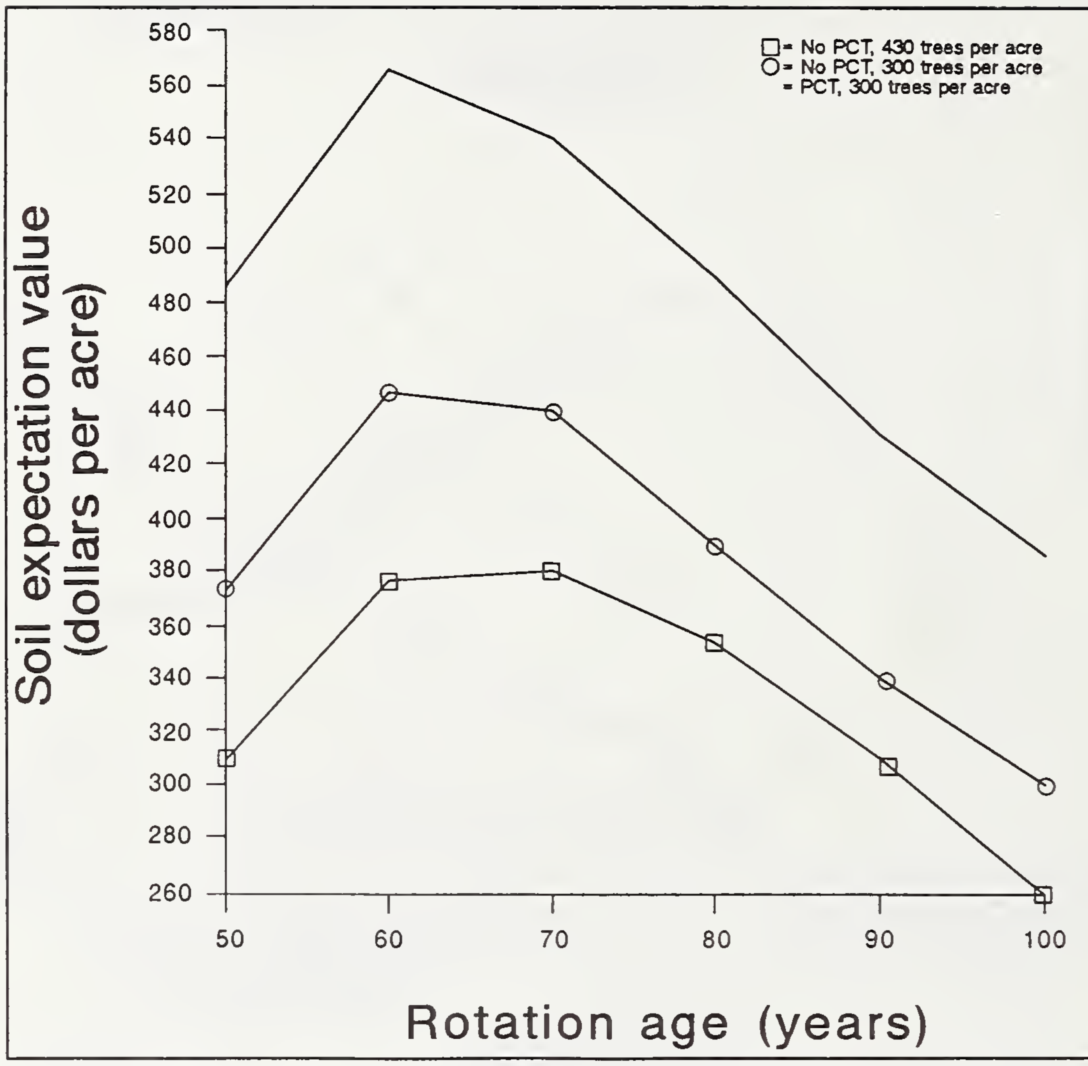

Figure 12—Soil expectation value on public ownership, site class 4, high price assumption, and 4-percent interest.

Early Stand Treatments

Stocking level and precommercial thinning—Initial stand density was inversely related to the SEV of the resulting optimal management regime: the lower the initial stand density, the higher the SEV of the associated optimal management regime. In all cases, the best strategy was to aim for the lowest initial stand density we considered, whether or not the stand was precommercially thinned.

A financial premium was usually realized for selecting well-spaced crop trees through precommercial thinning. In most cases, for the same initial stand density, it was beneficial to precommercially thin to obtain that density, as opposed to planting to that density. In some circumstances (such as a high interest rate combined with a low price assumption or a poor site quality, or both) the most profitable strategy was to plant to this low initial stand density and not precommercially thin (fig. 11).

Fertilization—The financially optimal management regimes all included fertilization. The investment in fertilization always resulted in a higher net financial return at the end of the rotation than when fertilization was not done. The increase in net financial return from fertilization ranged from $17 to $175 per acre. In preliminary DP/DFSIM runs, we compared the profitability of six different fertilization regimes: fertilization at age 30, 40, 50, 60, or 70 years, or no fertilization. The management regime with the highest SEV always included fertilization as soon as possible. This result is the same as that found by Johnson and Sleavin (1986).

Other Characteristics of Optimal Management Regimes

The optimal rotation age was influenced most by ownership category and site productivity. Optimal rotation ages on private lands ranged from 40 to 50 years as compared to 50 to 70 years on public lands, with rotation age increasing with decreasing site productivity in both ownership categories. As shown in figures 1 through 12, the optimal rotation age was generally not influenced by changes in initial stand density and precommercial thinning combinations in the same management situation. In some cases, fertilization decreased the optimal rotation age by a decade.

Commercial thinning increased net revenue by giving an earlier financial return and by increasing the final stand diameter. The financially optimal management regimes for some of the longer rotation ages included up to five commercial thinnings. The overall financially optimal management regime for each management situation was typically, however, one of the shorter rotation ages with one or two thinnings. Some of the optimal management regimes, especially on low site classes, had no thinnings. The increase in financial return resulting from commercial thinning ranged from $0 to $150 per acre on private lands and $0 to $20 per acre on public lands.

High-cost reforestation decreased the financial return at the end of the rotation but generally did not alter the sequence of treatments in the optimal management regimes. The financially optimal management regimes for low-cost and high-cost reforestation were the same as long as the returns justified keeping the site in forest production.

The per-entry management costs associated with commercial thinnings and final harvest (timber sale preparation, timber harvest administration, and road reconstruction) had a major impact on the optimal pattern of thinnings and final harvest. As these costs increased from private ownership cost levels to those of public ownership cost levels, we found that the financially optimal management regimes included fewer thinnings, and they were taken later in the rotation. Under a 4-percent interest rate assumption, private owners with higher fixed harvest costs than those used in our study could, therefore, conclude that their optimal management regime would resemble that of a public owner: fewer thinnings later in the rotation.

Factors Influencing Soil Expectation Value

Based on optimization runs for a few management situations, we concluded that taxes were neutral; they lowered the SEV of the optimal management regimes but did not alter the optimal management regimes in any other way. We therefore calculated the SEV after taxes from the management regimes that were optimal before

taxes. We estimated an ordinary least-squares relation between our before-tax SEV data and after-tax SEV data as a rough estimation rule for the SEV after taxes in a given management situation:

$$SEV_{at} = -52.0 + 0.65\ SEV_{bt}\ ,$$

where

SEV_{at} = SEV after tax, and
SEV_{bt} = SEV before tax.

Interest rates and prices affected the absolute amount of the SEV more than any other variables. Taxes and ownership category had less effect, and reforestation difficulty had least effect of all in terms of absolute amount of SEV.

Unprofitable Forestry in Southwest Oregon?

We defined management situations for which it was not possible to find management regimes with a positive SEV as "unprofitable." Such management situations discourage the practice of forestry in an economic sense. Under the following management situations, all with a low price assumption, the financially optimal management regimes had a negative SEV:

Ownership category	Tax situation	Reforestation difficulty	Site class	Interest rate
				Percent
Private	Before tax	High	3	6
	After tax	High	3	6
	Before tax	Low	3	6
	After tax	Low	3	6
	Before tax	High	2	6
	After tax	High	2	6
Public		High	3	4
		Low	4	4
		High	4	4

All other management situations gave a positive SEV.

Institutional Constraints

We assumed no constraints were imposed on forest management in our analysis. Stands were analyzed independently. Forest management on National Forests is constrained by the requirement that in most cases final harvest cannot occur before mean annual increment for the stand has reached 95 percent of its maximum value. The optimal rotation ages we report are often shorter than this constraint would allow. Other constraints that often exist on reforestation and stand management are (1) a state law that acres must be reforested after harvest and (2) an even-flow constraint on the harvest from a forest.

Reforestation requirement—One of the institutional constraints imposed on forest management in southwest Oregon is the State Forest Practices Act, which requires that a minimum of 100 seedlings per acre be established on cutover lands within 4 years after final harvest (Oregon Forest Protection Association 1972). Our optimization criterion of soil expectation value does not consider this constraint. In other words, we treated reforestation as a discretionary investment cost in our analysis, without a reforestation requirement associated with final harvest.

When a reforestation requirement is imposed, reforestation is a condition that must be met to harvest the existing stand. From a financial analysis point of view, meeting this requirement is no longer discretionary. The cost of meeting this requirement now becomes a cost of harvesting the existing stand rather than a cost attributed to establishing the future stand. The cost of meeting the reforestation requirement for the new stand is removed from the reforestation cost of the new stand and is added to the cost of harvesting the existing stand.

Mathematically, SEV without the reforestation requirement is:

$$(R\text{-}C(1+i)^r) / (1+i)^r + (R\text{-}C(1+i)^r) / (1+i)^{2r} + (R\text{-}C(1+i)^r) / (1+i)^{3r} + \ldots ,$$

where

R = the net revenue from the harvest,
C = the reforestation cost,
i = the interest rate, and
r = the rotation age.

For simplicity, we assume no intermediate harvest, no intermediate costs, and that the cost of meeting the minimum reforestation requirement and the cost of reforestation at the desired level are the same. This series converges to the SEV formula:

$$(R\text{-}C(1+i)^r) / ((1+i)^r - 1) .$$

SEV with the reforestation requirement (SEV') is:

$$(R\text{-}C) / (1+i)^r + (R\text{-}C) / (1+i)^{2r} + (R\text{-}C) / (1+i)^{3r} + \ldots .$$

This series converges to:

$$(R\text{-}C) / ((1+i)^r - 1) .$$

SEV' will always be greater than SEV by the difference:

$$((R\text{-}C) / (1+i)^r - 1) - (R - C(1+i)^r) / ((1+i)^r - 1) .$$

			Without reforestation requirement		With reforestation requirement		
			Decision	Value	Decision	Value	Loss
SEV>0	R>0	R+SEV>0	HP	R+SEV	HP	R+SEV	0
	R<0	R+SEV>0	HP	R+SEV	HP	R+SEV	0
		R+SEV<0	–	0	–	0	0
SEV<0	R>0	R+SEV>0	H	R	HP	R+SEV	$\|SEV\|$
		R+SEV<0	H	R	–	0	R
	R<0	R+SEV<0	–	0	–	0	0

where

SEV = soil expectation value without reforestation requirement

R = net revenue of existing stand without reforestation requirement

HP = harvest and plant

H = harvest only

– = do not harvest or plant

Figure 13—Decision outcomes and associated losses to the landowner from a reforestation requirement.

This difference reduces to the reforestation cost C. This does not mean that the landowners have gained an increase in the value of the property (the value of the existing stand plus the SEV if they reforest the property, the value of the existing stand if it is not reforested). A restriction on management options can have no effect or reduce the value of the property but cannot increase the value of the property. Figure 13 gives a complete treatment of the options and the financial cost of the reforestation requirement under various conditions. It shows the decision made and associated property value with and without the reforestation requirement for all possible values of SEV and existing stand value. The loss associated with the reforestation requirement, or the reduction in property value, is the difference between the property value without the reforestation requirement and the property value with the reforestation requirement.

If SEV without the reforestation requirement is positive, the wealth-maximizing landowners do the reforestation with or without the restriction. In that case, the increase in SEV is merely a paper transaction not affecting the value of the property because the property is managed the same with or without the restriction. This apparent increase in SEV comes about at the cost of an equal apparent decrease in the value of the existing stand. The net effect is no change in value of the property as a result of imposing the reforestation requirement.

If the SEV without the reforestation requirement is negative, the landowners may incur a reduction in the value of the property, because they will manage the property differently depending on whether the reforestation requirement is in effect. In the absence of a reforestation requirement, the wealth-maximizing landowners would harvest the existing stand and convert the land to some other use, which might be to let it stand idle or to sell the land. They thereby avoid incurring the negative SEV associated with managing the future stands. The reforestation requirement eliminates this option. If the absolute value of the negative SEV is less than R (the value of the existing stand without the reforestation requirement), that is, $R + SEV > 0$, the landowner will harvest and plant in accordance with the reforestation requirement. The loss will be the absolute value of the SEV. Usually the loss will be less than C, the cost of reforestation, because by incurring the reforestation cost, the landowner gains the revenue from the future stands. If this revenue is very small, the loss may approach C. If the absolute value of the negative SEV exceeds R, the loss can be limited to the value of the existing stand (R) by not harvesting the stand and thereby avoiding the requirement to reforest.

Even-flow constraint—It can be argued that in a financial analysis, forest stands should not be considered as independent entities in a per-acre analysis but rather as interconnected parts in an analysis of the whole forest. With an even-flow constraint, the rate of harvest of the existing stands is tied to the growth of future stands to ensure that the harvest will not decrease because of harvesting at a faster rate than can be sustained. The financial cost of an even-flow restriction can be quite high when the value of the existing stands is high and the contribution to SEV of managing future stands is highly negative. When the financially optimal unconstrained rate of harvest for the current period exceeds the rate permitted with an even-flow constraint, growth-increasing investments produce an allowable-cut effect. The apparent financial return of growth-increasing investments is increased in the same way that the SEV of future stands is increased with a reforestation requirement. The apparent increase in SEV is offset by an apparent loss in the value of the existing stands. As with the reforestation requirement, the imposition of a restriction on the rate of harvest either can have no effect on the value of the property or can reduce the value, but it cannot increase it. When an even-flow constraint causes a financial loss, the landowners have options for limiting the loss. These options involve investments in growth-increasing treatments that allow the landowner to recapture some of the lost value. For a more detailed discussion of this issue see Schweitzer and others (1972). When SEV was negative, a positive SEV might result if evaluated with an even-flow constraint. That can be determined, however, only case by case.

Conclusions

Regardless of the assumptions, the same management regimes were financially optimal: a low initial stand density, a rotation of 40 to 50 years on private lands or 50 to 70 years on public lands, and one or two commercial thinnings. In the same management situation, a low initial stand density always gave greater net returns than did higher stand densities. In most cases, it was advantageous to precommercially thin to obtain the low initial stand density. Factors such as low stumpage prices, high interest rate, and low sites that are difficult to reforest may combine, however, in a way to make it less profitable to precommercially thin to a low initial stand density than to plant at the same low density with no precommercial thinning.

A single application of fertilizer was profitable in every management situation. We found that fertilizing as soon as possible after the juvenile growth stage gave the highest financial returns. Although DFSIM does not reliably predict a stand's response to fertilization in the juvenile growth stage, the trends in our results suggest that fertilization in the juvenile growth stage may give even higher returns than fertilizing after the stand has emerged from the juvenile growth stage. There seems to be a financial advantage to removing up to 50 percent of the total stand volume through one or two commercial thinnings rather than cutting the entire volume at final harvest.

Some management situations with factors such as unfavorable investment conditions (low prices, high interest rate), high-cost reforestation, and low site productivity discouraged management. A positive net discounted return could not be obtained under these conditions, thereby indicating that costly early stand treatments may not be financially justifiable on low-productivity sites that are difficult to reforest unless investment conditions are highly favorable.

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Metric Equivalents

1 inch = 2.54 centimeters
1 foot = 0.305 meter
1 mile = 1.61 kilometers
1 acre = 0.405 hectare
1 pound = 0.453 kilogram

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Appendix 1

Reforestation Cost Data

We obtained data on typical reforestation conditions and associated costs from interviews with silviculturists in southwest Oregon. Tables 4 and 5 give the breakdown of the reforestation costs used for the different stocking levels for each ownership class. The prescriptions and costs are considered representative of 1985 conditions in southwest Oregon but not all-inclusive of the range of actual situations encountered in this region. Furthermore, the general pattern of decreasing costs as site quality decreases has important exceptions. For example, low-quality sites or conditions exist where relatively expensive silvicultural treatments are required to ensure adequate reforestation. Conversely, high-quality sites exist where very little expense is needed to achieve reforestation. The reforestation costs summarize several reforestation activities (site preparation, planting, release and regeneration surveys) discounted to the age of stand establishment. We assumed no replanting was needed.

Table 4—Reforestation assumptions and costs on Federal lands in southwest Oregon

Site Class	Low-cost reforestation: Treatment	Low-cost reforestation: Cost	High-cost reforestation: Treatment	High-cost reforestation: Cost
		Dollars		*Dollars*
		Stocking: 430		
3	Stand exam and prescription[a]	10	Stand exam and prescription[a]	10
	Slash and burn[b]	200	Slash and burn[c]	300
	Planting[d]	200	Planting[e]	250
			Mulching or tubing[f]	100
	Regeneration surveys at ages 1, 3, and 5[g]	15	Regeneration surveys at ages 1, 3, and 5[g]	15
		425		675
4	Stand exam and prescription[a]	10	Stand exam and prescription[a]	10
	Slash and burn[b]	200	Slash and burn[c]	300
	Planting[d]	200	Planting[h]	220
			Mulching or tubing[f]	100
	Regeneration surveys at ages 1, 3, and 5[g]	15	Regeneration surveys at ages 1, 3, and 5[g]	15
		425		645
		Stocking: 300		
3	Stand exam and prescription[a]	10	Stand exam and prescription[a]	10
	Slash and burn[b]	200	Slash and burn[c]	300
	Planting[d]	137	Planting[e]	171
			Mulching or tubing[f]	69
	Regeneration surveys at ages 1, 3, and 5[g]	15	Regeneration surveys at ages 1, 3, and 5[g]	15
		362		565

See footnotes on next page.

Table 4—continued

Site Class	Low cost reforestation: Treatment	Cost	High cost reforestation: Treatment	Cost
		Dollars		*Dollars*
		Stocking: 300		
4	Stand exam and prescription[a]	10	Stand exam and prescription[a]	10
	Slash and burn[b]	200	Slash and burn[c]	300
	Planting[d]	137	Planting[h]	150
			Mulching or tubing[f]	69
	Regeneration surveys at ages 1, 3, and 5[g]	15	Regeneration surveys at ages 1, 3, and 5[g]	15
		362		544

[a] Entails field examination of selected timber stands before harvest and development of silvicultural prescriptions.
[b] Assumes a light cover of brush and slash after logging, thereby minimizing the costs of fire line construction and mop-up.
[c] Assumes a heavy cover of brush, hardwoods, and slash after logging, thereby requiring extensive precautions for burning.
[d] Includes the cost of seedlings (2-0 stock) and planting at 9- by 9-ft spacing (540 trees per acre) under easy conditions (800 trees/planter/day).
[e] Includes the cost of seedlings (2-1 stock) and planting at 9- by 9-ft spacing (540 trees per acre) under moderately difficult conditions (600 trees/planter/day).
[f] Assumes a paper mulch is required to minimize invasion of shrubby and herbaceous vegetation, or vexar tubes are needed to reduce animal damage.
[g] Assumes regeneration surveys at designated ages ($5/acre/survey) to monitor seedling survival and performance.
[h] Includes cost of seedlings (2-0 stock) and planting at 9- by 9-ft spacing (540 trees per acre) under moderately difficult conditions (600 trees/planter/day).

Table 5—Reforestation regimes and costs on forest industry lands in southwest Oregon

Site class	Low cost regime: Treatment	Cost	High cost regime: Treatment	Cost
		Dollars		*Dollars*
		Stocking: 430		
2	Aerial spray[a]	50	Slash and burn[b]	120
	Planting[c]	150	Planting[d]	185
			Vexar tubes[e]	50
	Aerial spray at age 4[f]	50	Aerial spray at ages 3 and 6[f]	100
	Regeneration surveys at ages 2 and 5[g]	8	Regeneration surveys at ages 1, 3, and 5[g]	12
		258		467

See footnotes on next page.

Table 5—continued

Site class	Low cost regime: Treatment	Low cost regime: Cost	High cost regime: Treatment	High cost regime: Cost
		Dollars		*Dollars*
		Stocking: 430		
3	Aerial spray[a]	50	Slash and burn[b]	120
	Planting[c]	150	Planting[h]	140
	Aerial spray at age 4[f]	50	Aerial spray at ages 3 and 6[f]	100
	Regeneration surveys at ages 2 and 5[g]	8	Regeneration surveys at ages 1, 3 and 5[g]	12
		258		372
		Stocking: 300		
2	Aerial spray[a]	50	Slash and burn[b]	120
	Planting[c]	104	Planting[d]	128
			Vexar tubes[e]	35
	Aerial spray at age 4[f]	50	Aerial spray at ages 3 and 6[f]	100
	Regeneration surveys at ages 2 and 5[g]	8	Regeneration surveys at ages 1, 3, and 5[g]	12
		212		395
3	Aerial spray[a]	50	Slash and burn[b]	120
	Planting[c]	104	Planting[h]	97
	Aerial spray at age 4[f]	50	Aerial spray at ages 3 and 6[f]	100
	Regeneration surveys at ages 2 and 5[g]	8	Regeneration surveys at ages 1, 3 and 5[g]	12
		212		329

[a] Assumes a light cover of brush and slash after logging, thereby favoring an aerial spray of herbicide for site preparation.
[b] Assumes a relatively heavy cover of brush, hardwoods and slash after logging, thereby requiring hand slashing and heli-torching of the residual vegetation and slash.
[c] Includes the cost of seedlings (2-0 stock) and planting at 9- by 9-ft spacing (540 trees/acre) under moderately difficult conditions (600 trees/planter/day).
[d] Includes the cost of seedlings (2-1 stock) and planting at 9- by 9-ft spacing (540 trees/acre) under easy conditions (800 trees/planter/day).
[e] Assumes Vexar tubes applied to half of the seedlings when planting to reduce clipping by mountain beaver.
[f] Assumes an aerial release spray(s) of herbicide to release seedlings from brush competition ($50/spray).
[g] Assumes regeneration surveys at designated ages ($4/acre/survey) to monitor seedling survival and performance.
[h] Includes the cost of seedlings (2-0 stock) and planting at 9- by 9-ft spacing (540 trees/acre) under easy conditions (800 trees/planter/day).

Appendix 2

Per Unit Volume Logging Costs

Tables 6 and 7 give the logging costs (excluding fixed costs) used in our analysis.

Table 6—Stump-to-truck logging costs for commercial thinnings (excluding fixed costs)

Diameter at breast height	Cubic feet volume harvested per acre					
	500	1000	1500	2000	5000	10000
Inches	*- - - - - - - - - - Dollars per thousand cubic feet - - - - - - - - - -*					
6	739	708	691	677	622	617
8	594	565	550	539	493	488
10	489	461	448	438	399	395
12	408	381	369	360	327	323
14	344	318	307	299	271	267
16	294	269	259	252	227	224
18	380	308	281	267	228	221
20	340	269	243	229	193	186
22	316	245	219	205	171	164
24	305	235	209	195	162	155

Table 7—Stump-to-truck logging costs for clearcut harvests (excluding fixed costs)

Diameter at breast height	Cubic feet volume harvested per acre					
	500	1000	1500	2000	5000	10000
Inches	*- - - - - - - - - - Dollars per thousand cubic feet - - - - - - - - - -*					
6	651	633	627	624	619	617
8	521	504	498	495	490	488
10	429	411	405	402	397	395
12	357	339	333	330	325	323
14	301	283	277	274	269	267
16	257	240	234	231	225	224
18	331	273	253	244	226	221
20	296	238	219	209	192	186
22	274	216	197	188	170	164
24	265	207	188	178	161	155

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Management guidelines for economically efficient early stand treatments were developed by identifying treatments that would maximize financial returns over the rotation for coast Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) in southwest Oregon. Short rotations and low stand densities (trees per acre) gave the highest financial returns in all cases. Usually precommercially thinning to a low stand density was more advantageous than planting at low density. Fertilization as soon as possible was always profitable. The financially optimal management regimes for low-cost and high-cost reforestation were identical if the returns justified keeping the site in forest production. Costly treatments were not financially justifiable on low-productivity sites where reforestation is difficult unless investment conditions are favorable.

Keywords: Douglas-fir (coast), financial analysis, stand-level optimization, young-growth management.

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